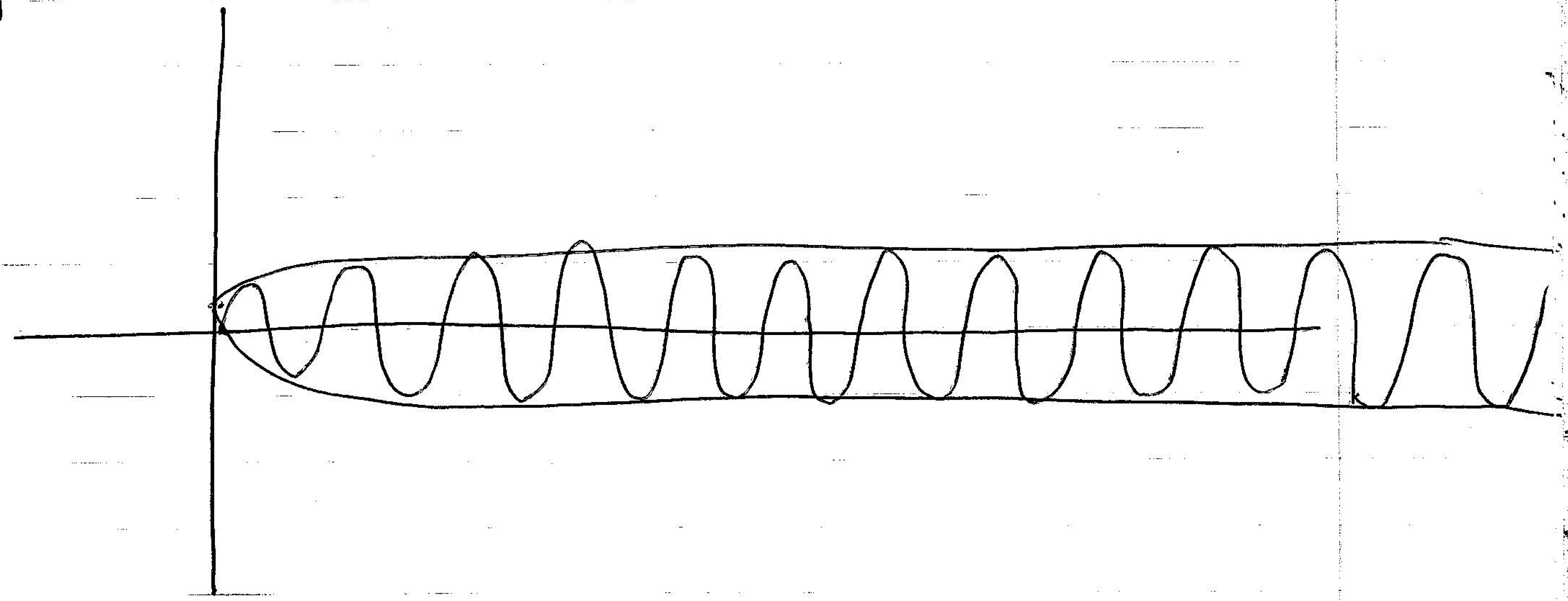
Frequency Response Methods

The steady state Response of a system to a sinusoidal input



1. Bode diagram 2. Polar-plot

1. Bode Diagram

* Steps to plot Bode diagram

1. Obtain the total transfer function $G(s)$
2. Find $G(jw) \Rightarrow G(jw) = Re + Im j$
3. obtain $\boxed{|G(jw)| = \sqrt{Re^2 + Im^2}}$ & $\boxed{\phi = \tan^{-1}\left(\frac{Im}{Re}\right)}$
4. Obtain the logarithemic gain

$= 20 \log |G(jw)|$ in dB

dB = deci Bell

$$\log \frac{P_2}{P_1} = \boxed{---} \text{ [Bell]}$$

$$\log \frac{V_2^2}{V_1^2} = \boxed{---} \text{ [Bell]}$$

$$\log \frac{V_2^2}{V_1^2} = 2 \log \frac{V_2}{V_1} = 20 \log \frac{V_2}{V_1} = \boxed{--} \text{ [dB]}$$

Ex Plot the Bode diagram of the following systems :-

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1. $G(s) = 4$

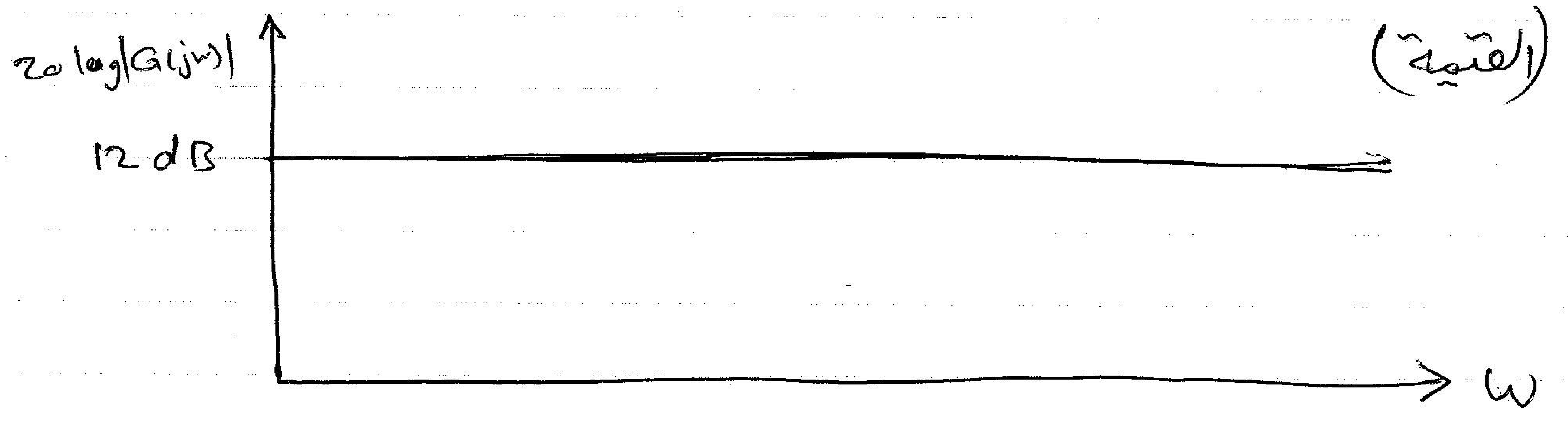
① $G(s) = 4$

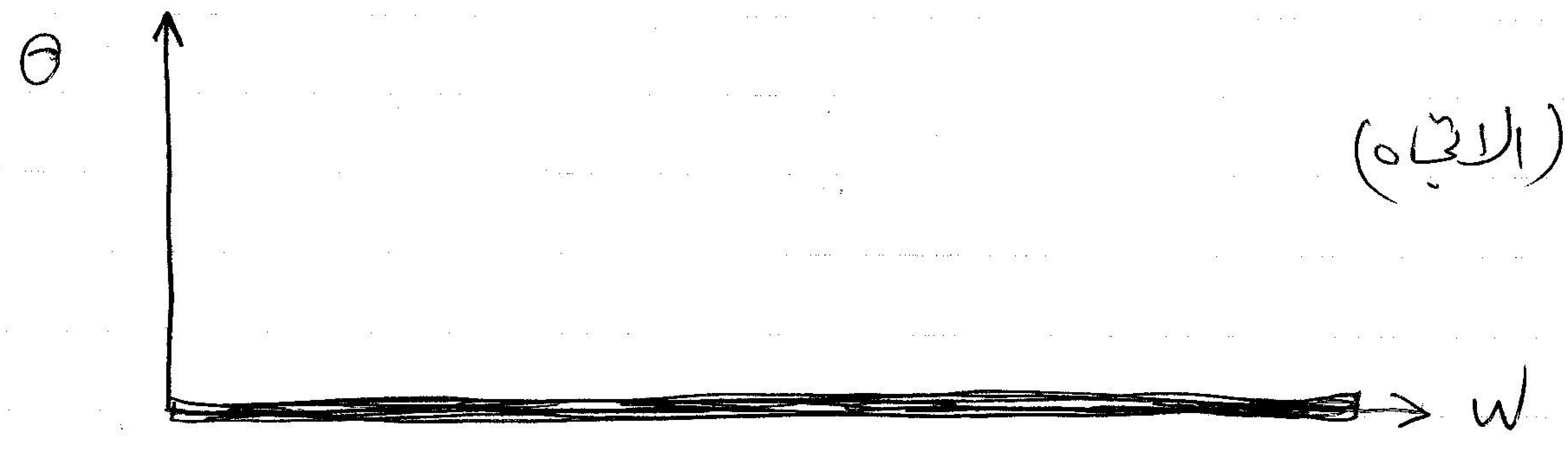
② $G(jw) = 4$

③ $|G(jw)| = 4$

$\theta = \tan^{-1} \frac{Im}{Re} = \tan^{-1} \frac{0}{4} = \tan^{-1} 0 = \boxed{\text{Zero}}$, 180 , ---

④ $20 \log |G(jw)| = 20 \log 4 = 12 \text{ dB}$





$\boxed{2.}$ $G(s) = -4$

① $G(s) = -4$

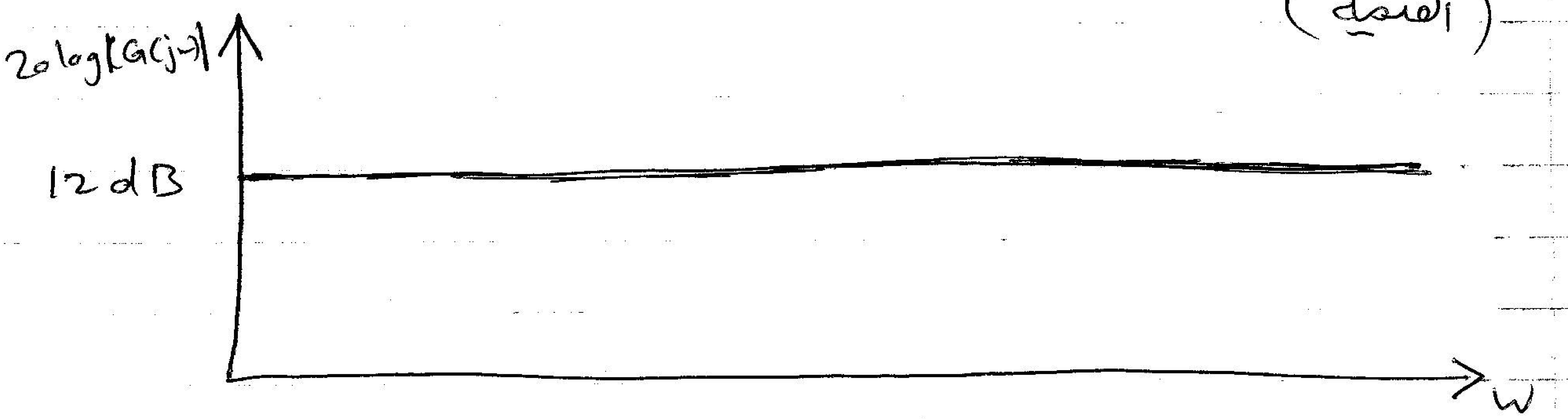
② $G(j\omega) = -4$

③ $|G(j\omega)| = 4$

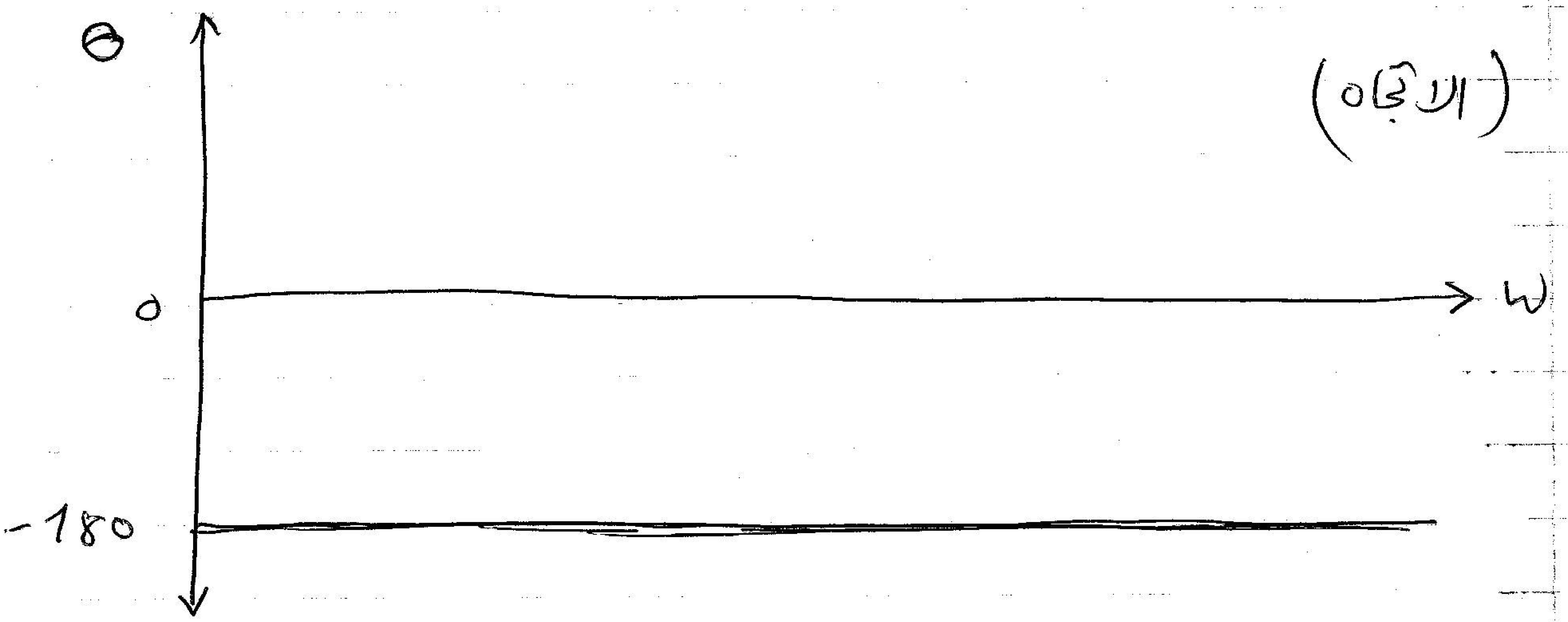
$$\theta = \tan^{-1}\frac{Im}{Re} = \tan^{-1}\frac{0}{-4} = \tan^{-1} 0 = \boxed{180^\circ}$$

−0.1	0	0.1
−5.7	0	5.7
	180	

(القيمة)



(الاتجاه)



3. $G(s) = s$

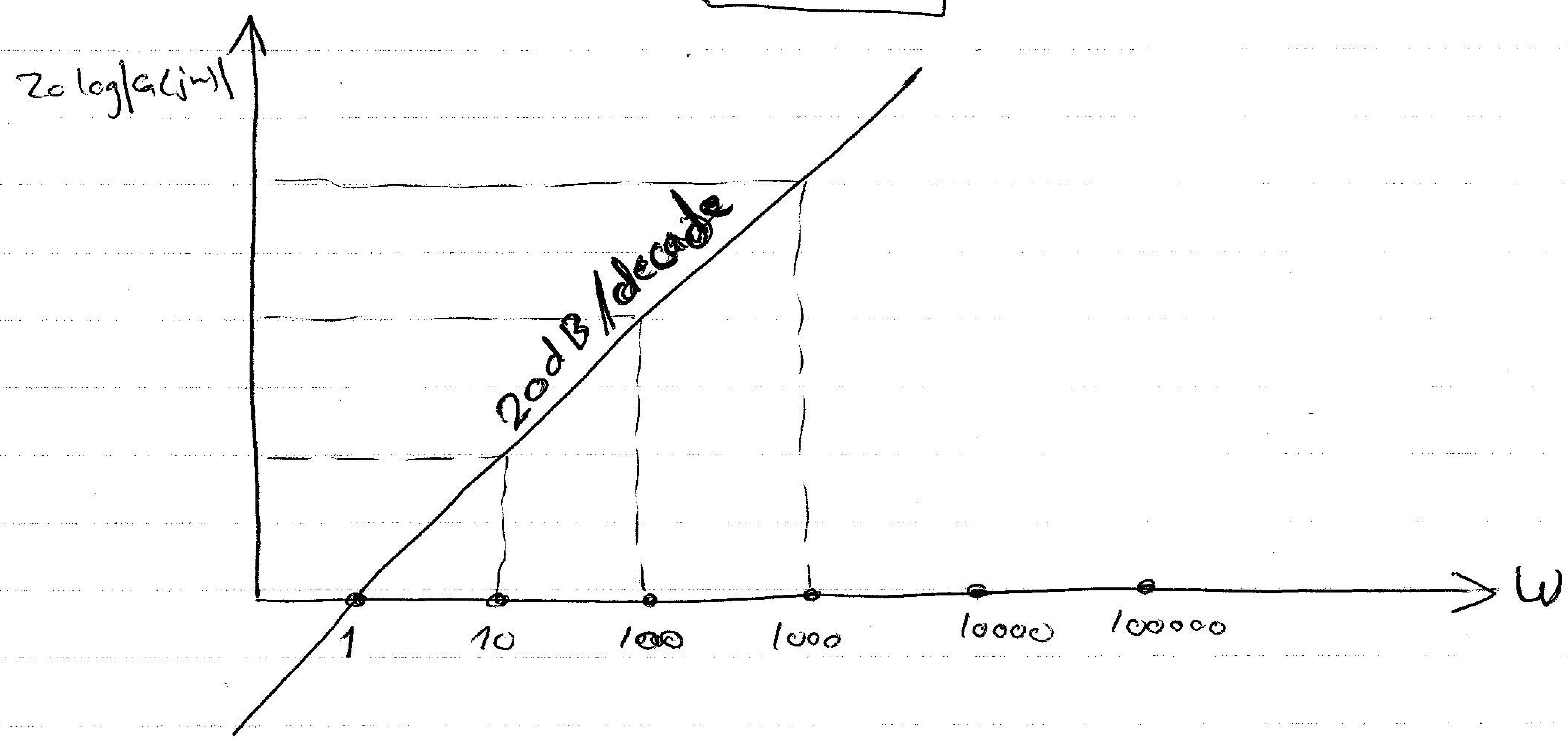
① $G(s) = s$

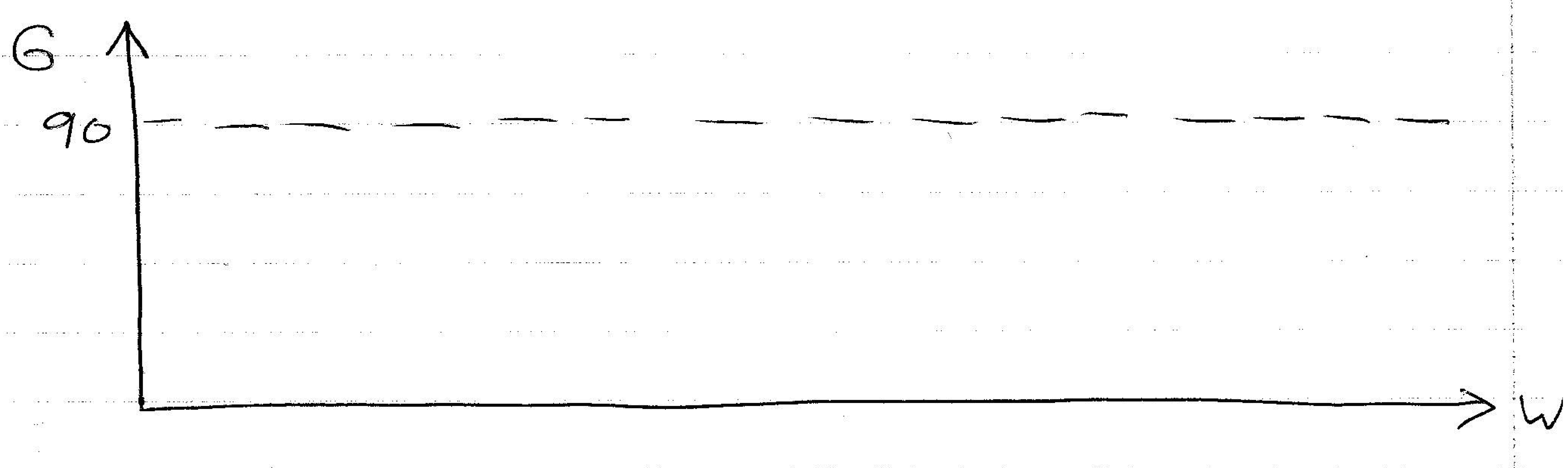
② $G(j\omega) = j\omega$

③ $|G(j\omega)| = \omega$

$\theta = \tan^{-1} \frac{Im}{Re} = \tan^{-1} \frac{\omega}{0} = \tan^{-1} \infty = \boxed{90^\circ}$

④ $20 \log |G(j\omega)| = \boxed{20 \log \omega}$





$\boxed{4.}$ $G(s) = S^2$

① $G(s) = S^2$

② $G(j\omega) = \cancel{\ } (j\omega)(j\omega)^2 = -1(\omega^2) = \boxed{-\omega^2}$

③ $|G(j\omega)| = \omega^2$

$\theta = \tan^{-1}\frac{Im}{Re} = \tan^{-1}\frac{0}{\omega^2} = \boxed{180^\circ}$

④ $20\log|G(j\omega)| = 20\log\omega^2 = \boxed{40\log\omega}$

ملاحظة :- كل (S) في البسط ~~يعطي~~ يعطينا

phase shift بمقدار 90°

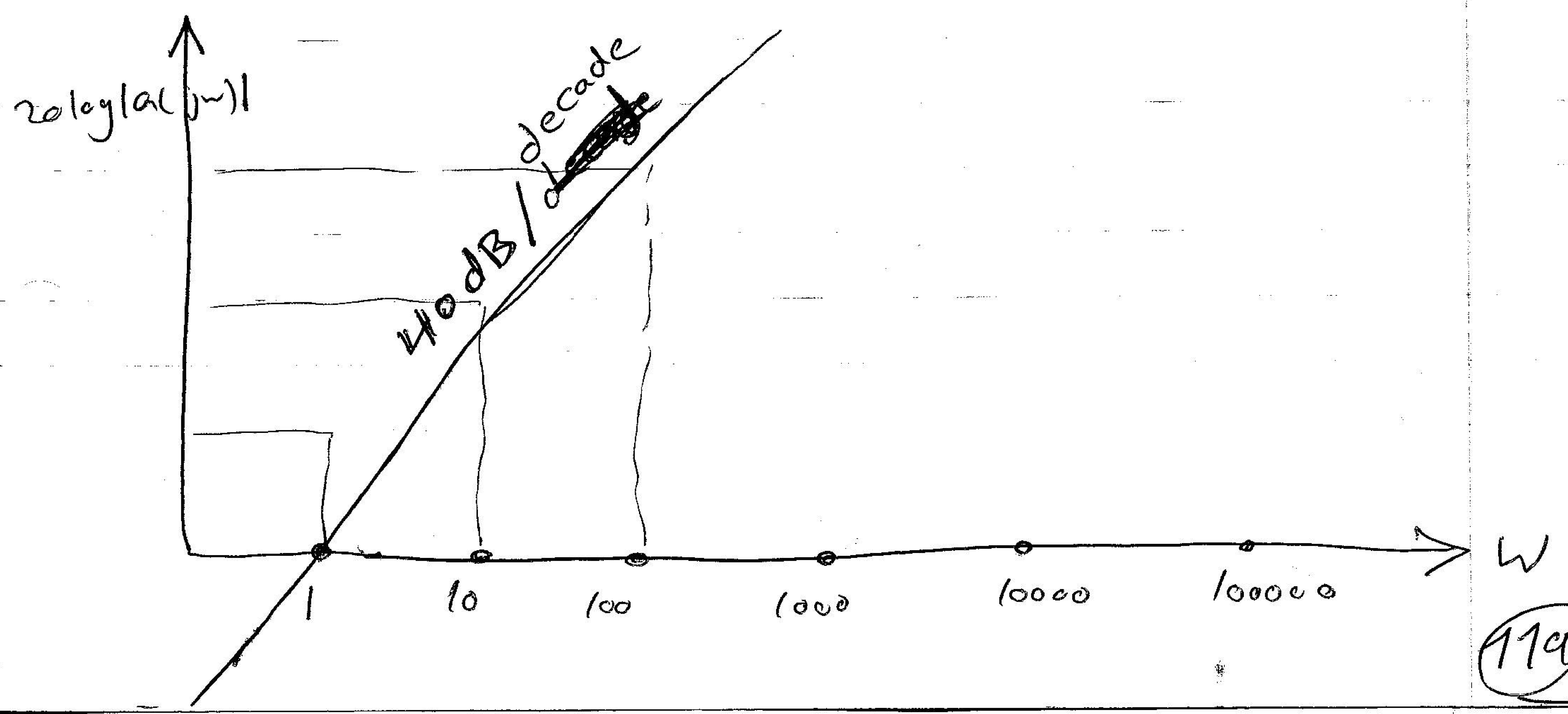
$90^\circ \leftarrow S$

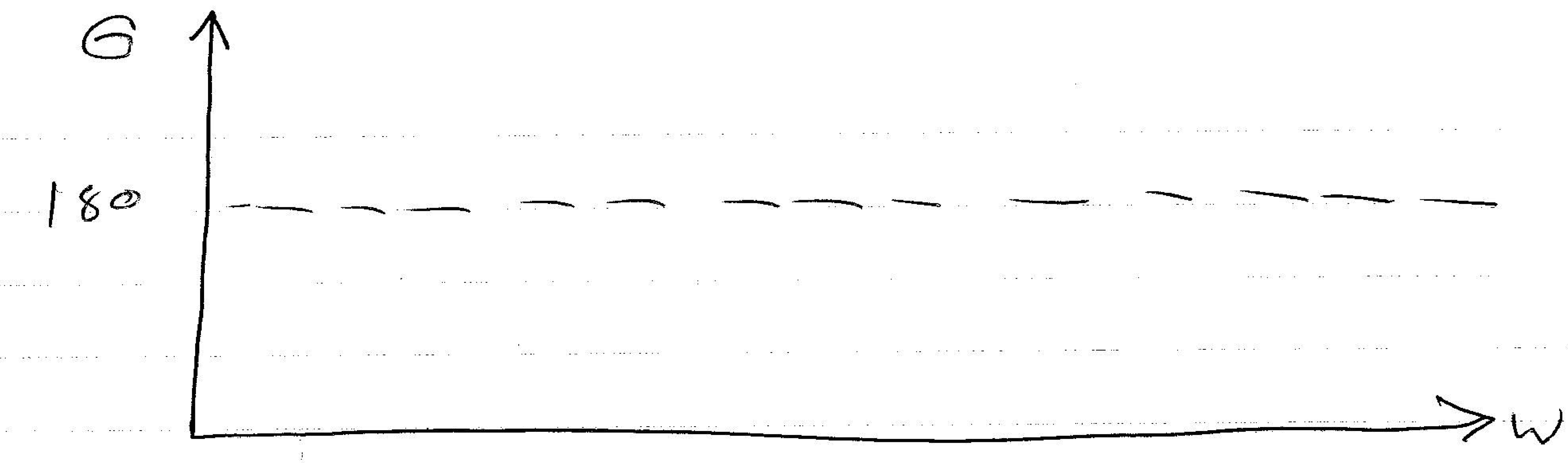
$180^\circ \leftarrow S^2$

$270^\circ \leftarrow S^3$

↓

وهكذا





$\boxed{5.}$ $G(s) = \frac{1}{s}$ $\boxed{j = -\frac{1}{j}}$

① $G(s) = \frac{1}{s}$

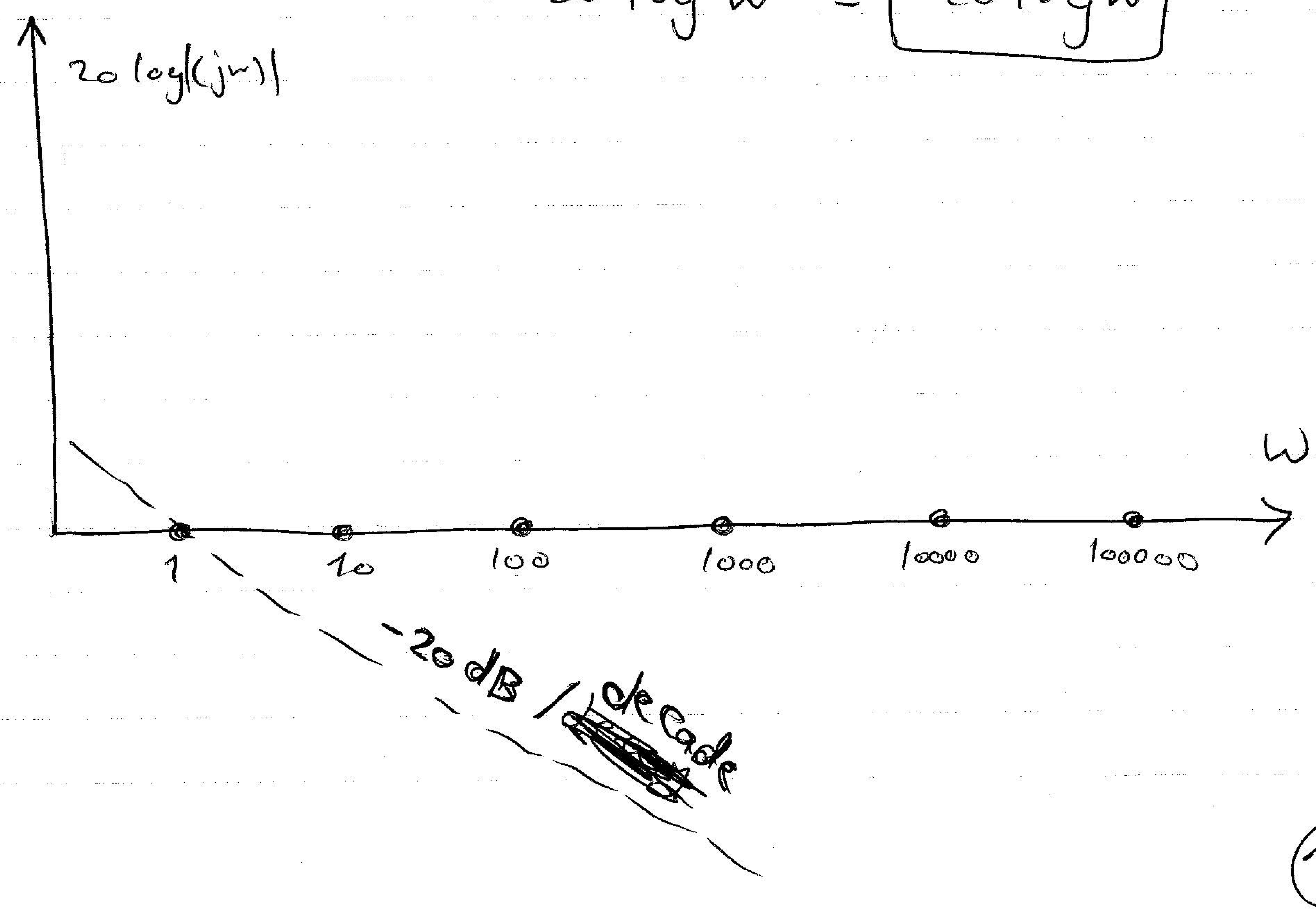
② $G(j\omega) = \frac{1}{j\omega} = \boxed{-\frac{1}{\omega} j}$

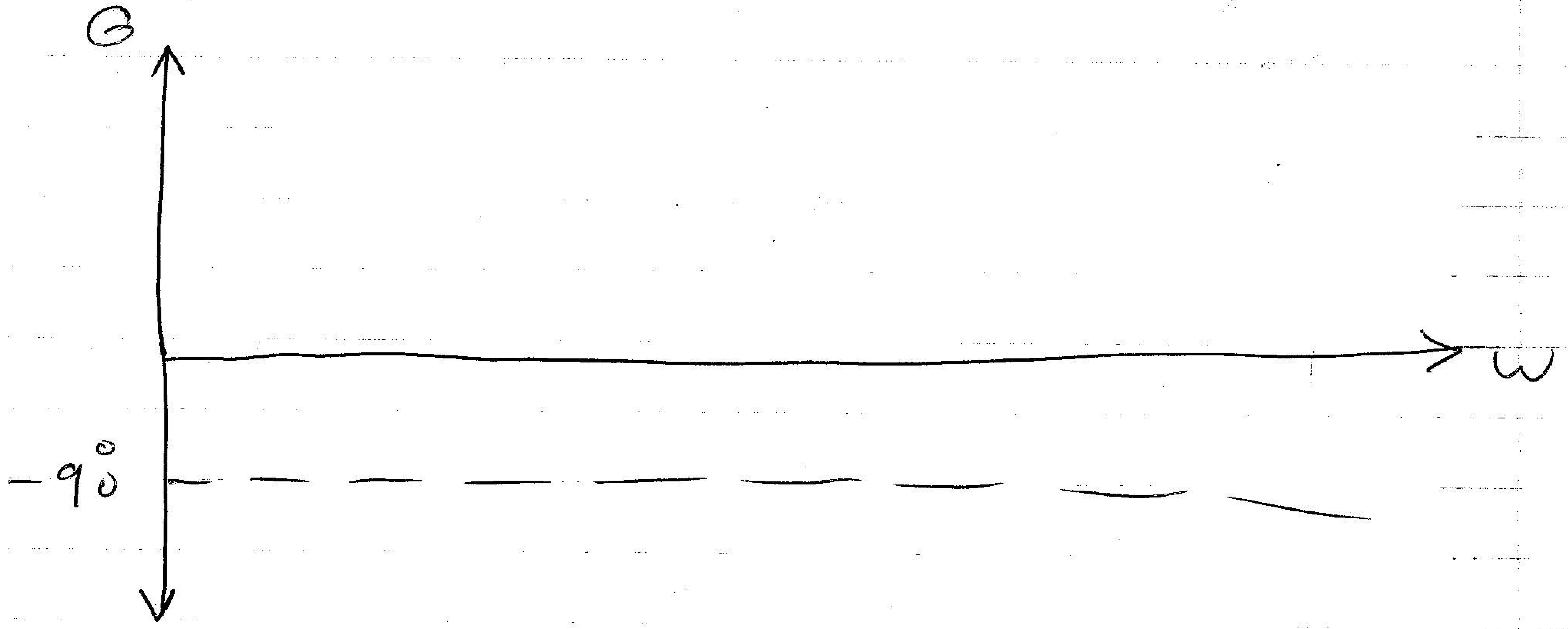
③ $|G(j\omega)| = \frac{1}{\omega}$

$\theta = \tan^{-1} \frac{Im}{Re} = \tan^{-1} \frac{-\frac{1}{\omega}}{0} = \tan^{-1} -\infty = \boxed{-90^\circ}$

④ $20 \log |G(j\omega)| = 20 \log \frac{1}{\omega} =$

$= 20 \log \omega^{-1} = \boxed{-20 \log \omega}$





* كل (S) في البسط تزيد الزاوية بـ phase shift مقدارة (90°)

* كل (S) في المقام تنقص الزاوية بـ phase shift مقدارة (90°)

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6. $G(s) = \frac{1}{s+1}$

① $G(s) = \frac{1}{s+1}$

② $G(j\omega) = \frac{1}{j\omega+1} * \frac{j\omega-1}{j\omega-1} = \boxed{\frac{j\omega-1}{-\omega^2-1}} = \frac{+1}{+(\omega^2+1)} - \frac{j\omega}{\omega^2+1}$

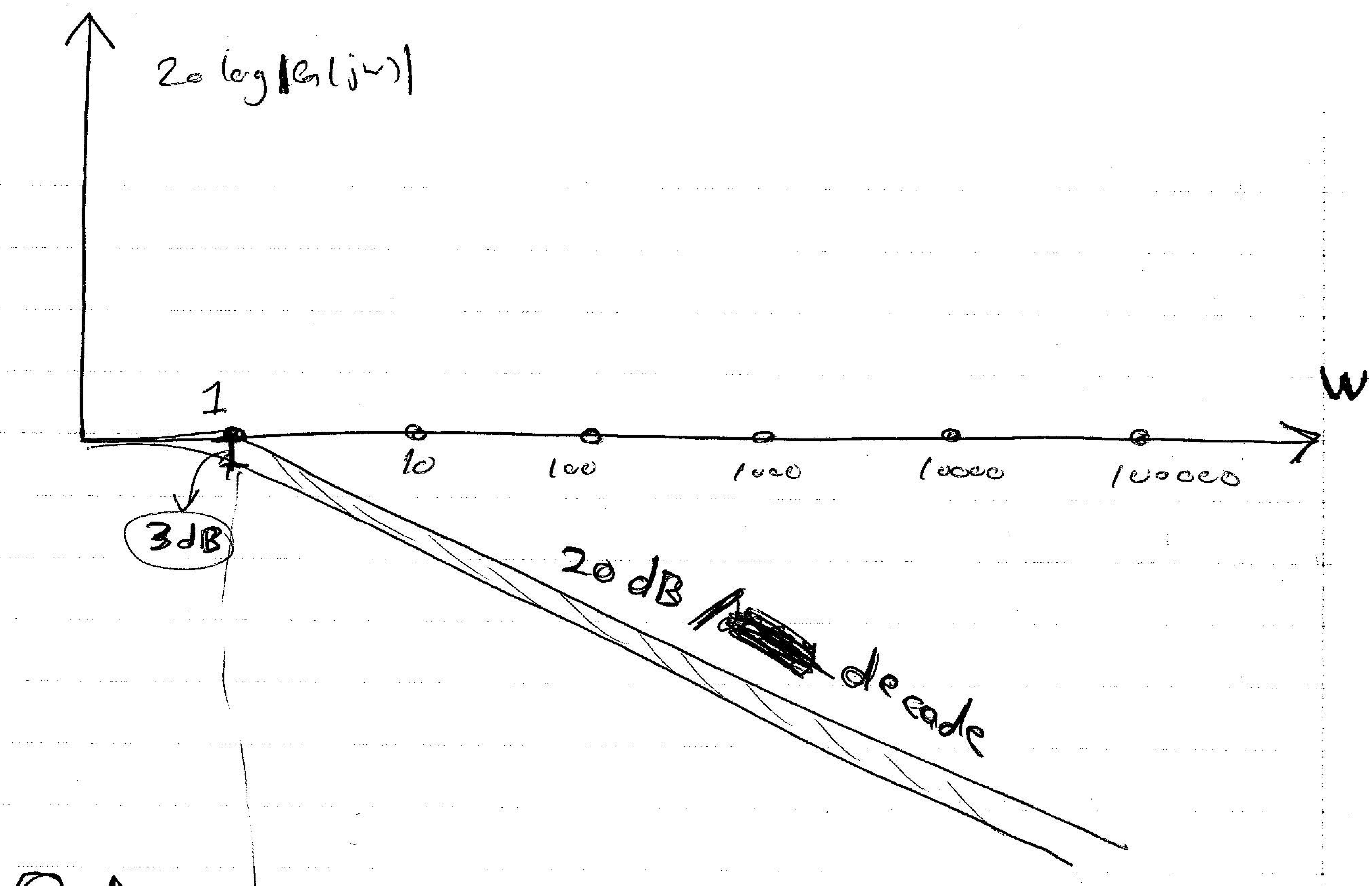
$$= \boxed{\frac{1}{\omega^2+1} - \frac{j\omega}{\omega^2+1}}$$

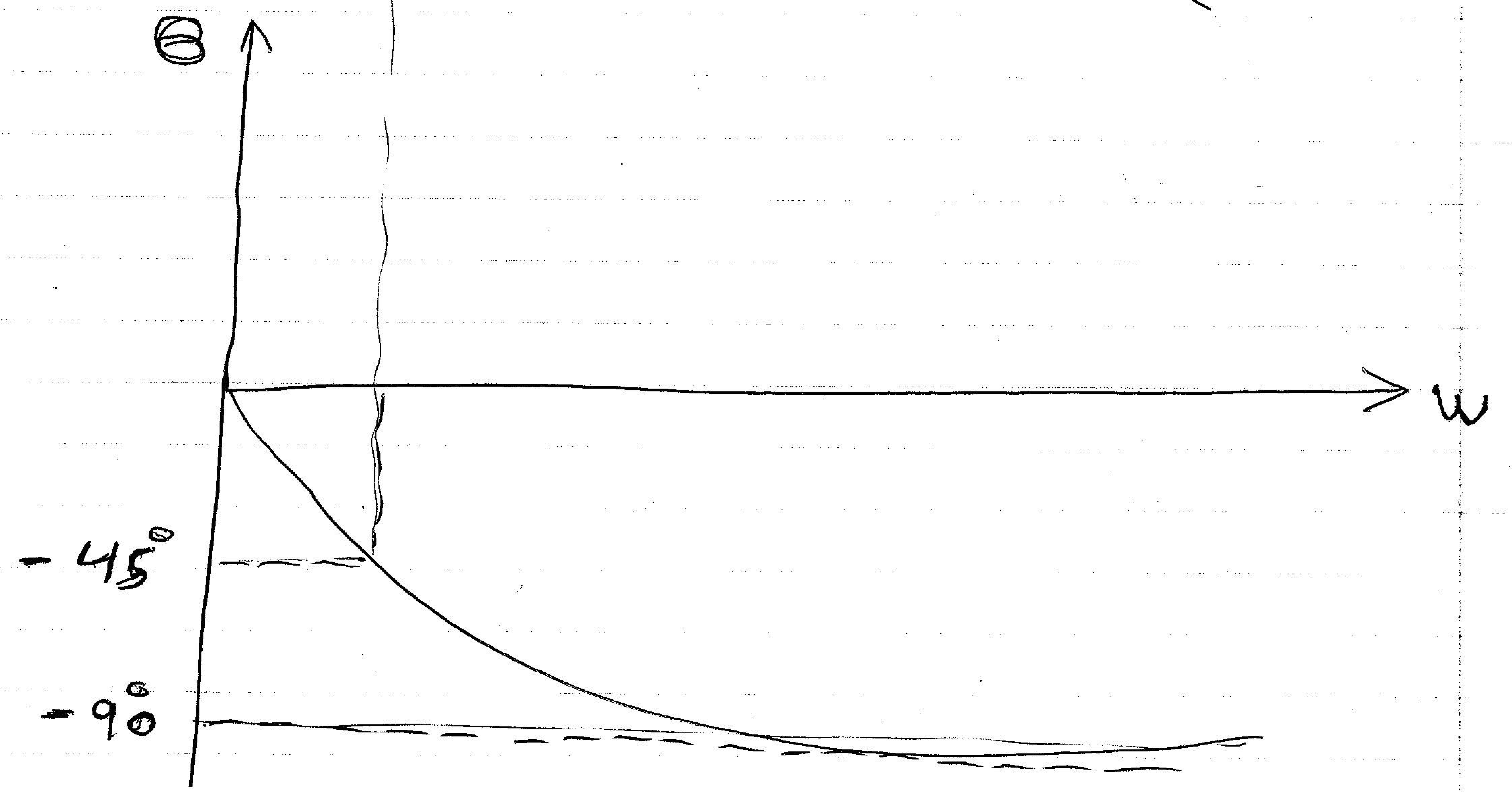
③ $|G(j\omega)| \Rightarrow$ ① $\omega \ll 1 \Rightarrow |G(j\omega)| = 1 \Rightarrow \theta = \text{zero}$

② $\omega \gg 1 \Rightarrow |G(j\omega)| = \frac{1}{\omega} \Rightarrow \theta = -90°$

③ $\omega = 1 \Rightarrow |G(j\omega)| = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45°$

④ $20\log|G(j\omega)|$


20 log |G(jw)|
1
w
10
100
1000
10000
100000
3dB
20 dB / decade


θ
w
-45°
-90°

Bode magnitude for Complex Systems

$$G(s) = \frac{2s+1}{(s+2)(s+3)(s+4)}$$

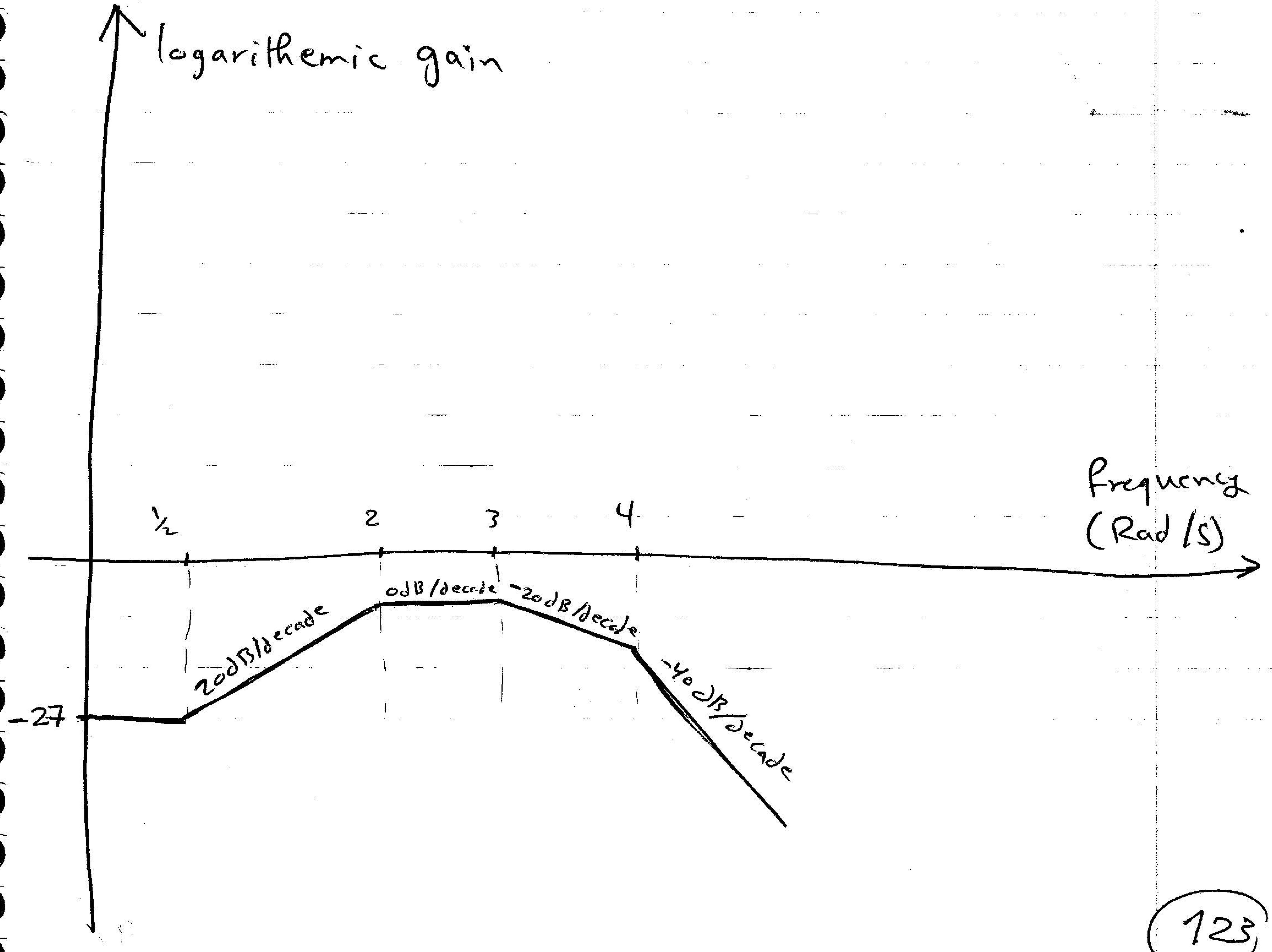
$w_c = \frac{1}{2}$, $w_c = 2$, $w_c = 3$, $w_c = 4$

① $\text{Log } 0 = 20\log 1 - 20\log 2 - 20\log 3 - 20\log 4$

$$= \boxed{20\log \tfrac{1}{24}} \approx \boxed{-27}$$

② find the Corner frequencies

③ Plot

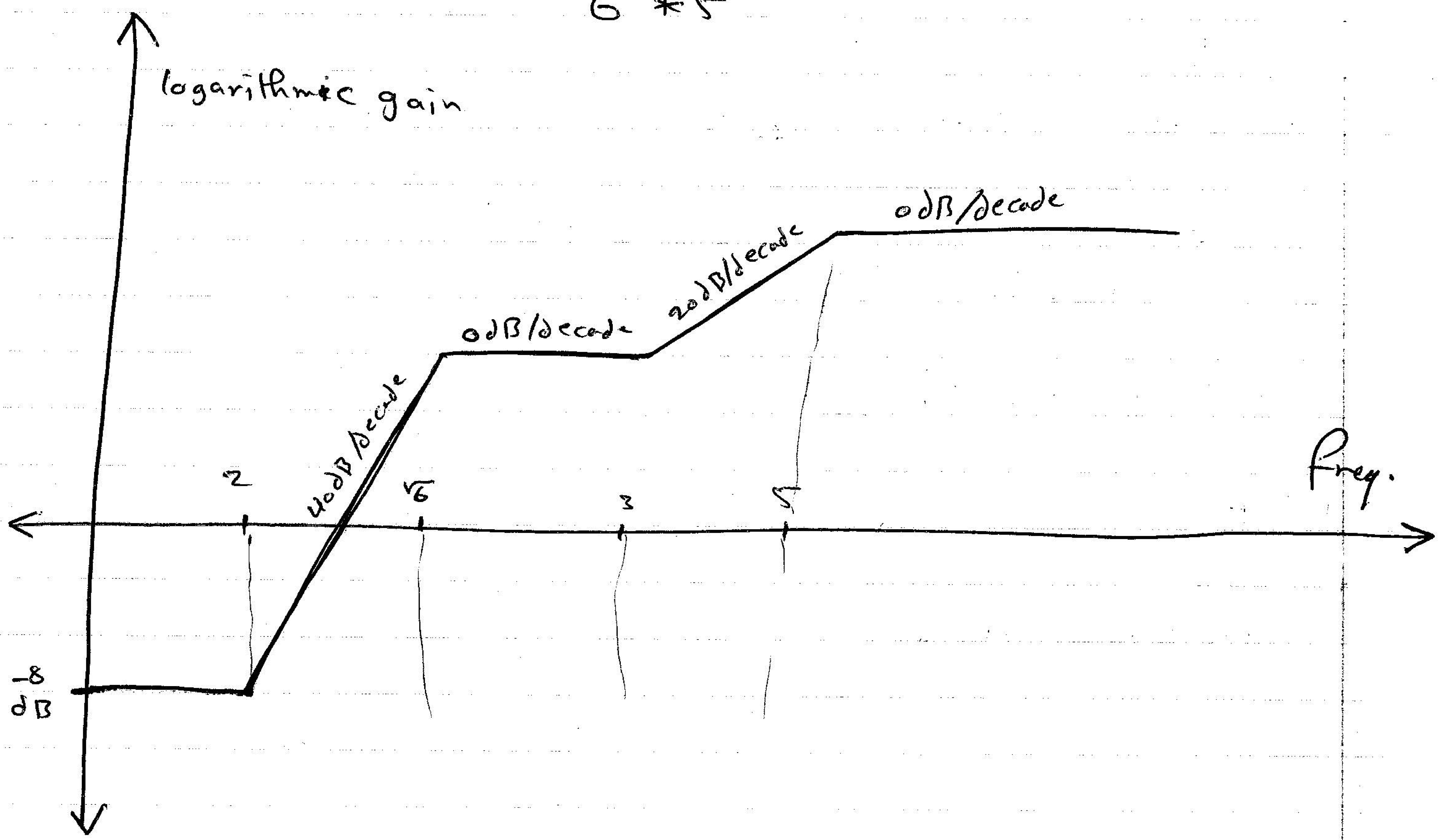


$w_c = 2$ $w_c = 3$

Ex $G(s) = \dfrac{(s+2)^2(s+3)}{(s^2+6)(s+5)}$

$w_c = \sqrt{6}$ $\boxed{w_c = 5}$

$\circledast$ $\log_0 = 20 \log \dfrac{2*2*3}{6*5} = 20 \log \frac{2}{5} \approx \boxed{-8}$

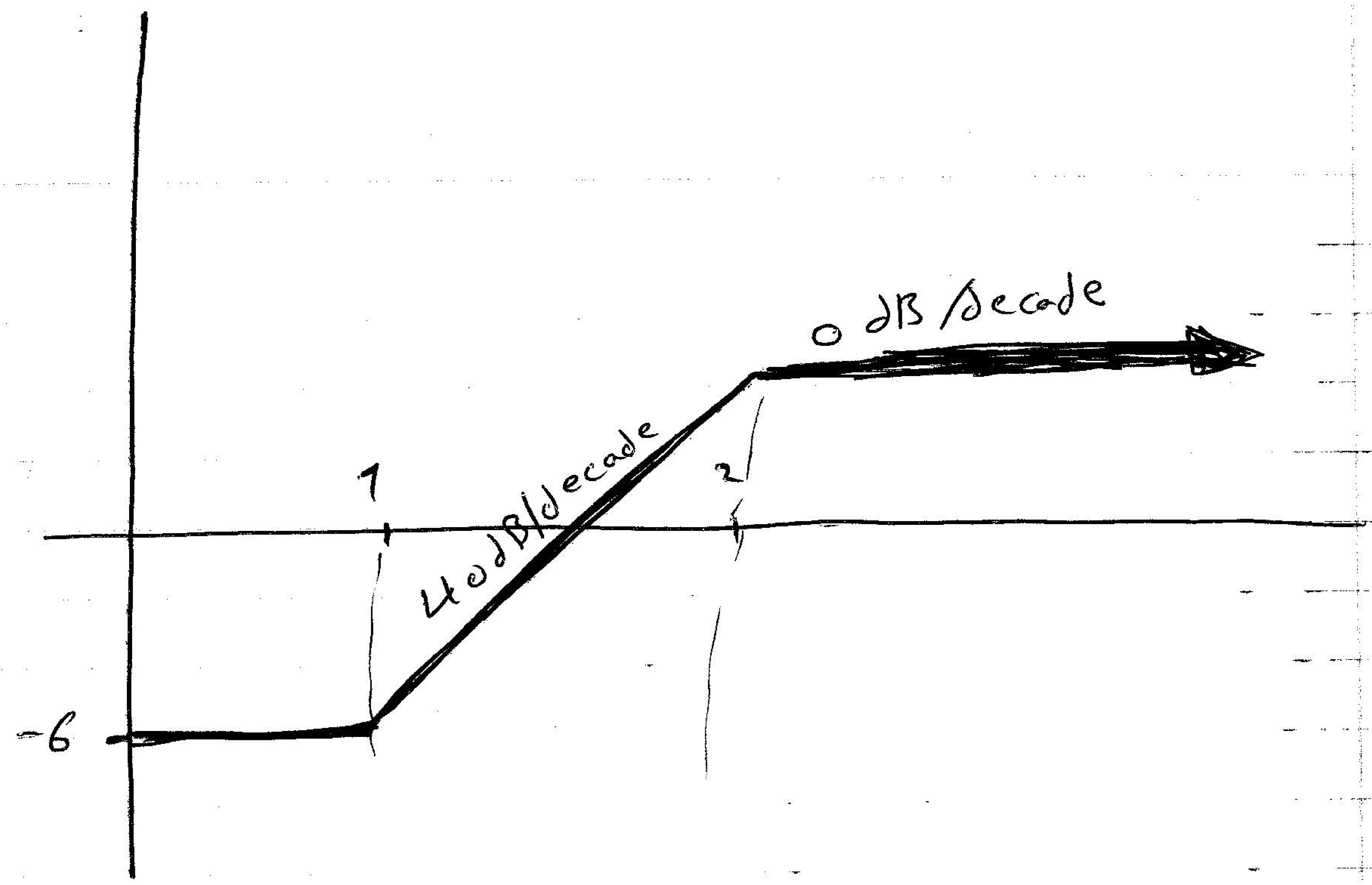


Ex $G(s) = \dfrac{s^2+2s+1}{s^2+2s+4}$

$w_c = 1$

$w_c = 2$

① $\log_0 = 20 \log \frac{1}{2} = \boxed{-6}$



2. ((Polar Plot))

the graph representing the relationship between Imaginary axis and real axis as frequency is changed.

1. Find $G(j\omega) = R(j\omega) + jX(j\omega)$
2. Find $|G(j\omega)| \angle \tan^{-1} \frac{X(j\omega)}{R(j\omega)}$

   OR make a table of relationship between R & $X(j\omega)$
3. plot

Example

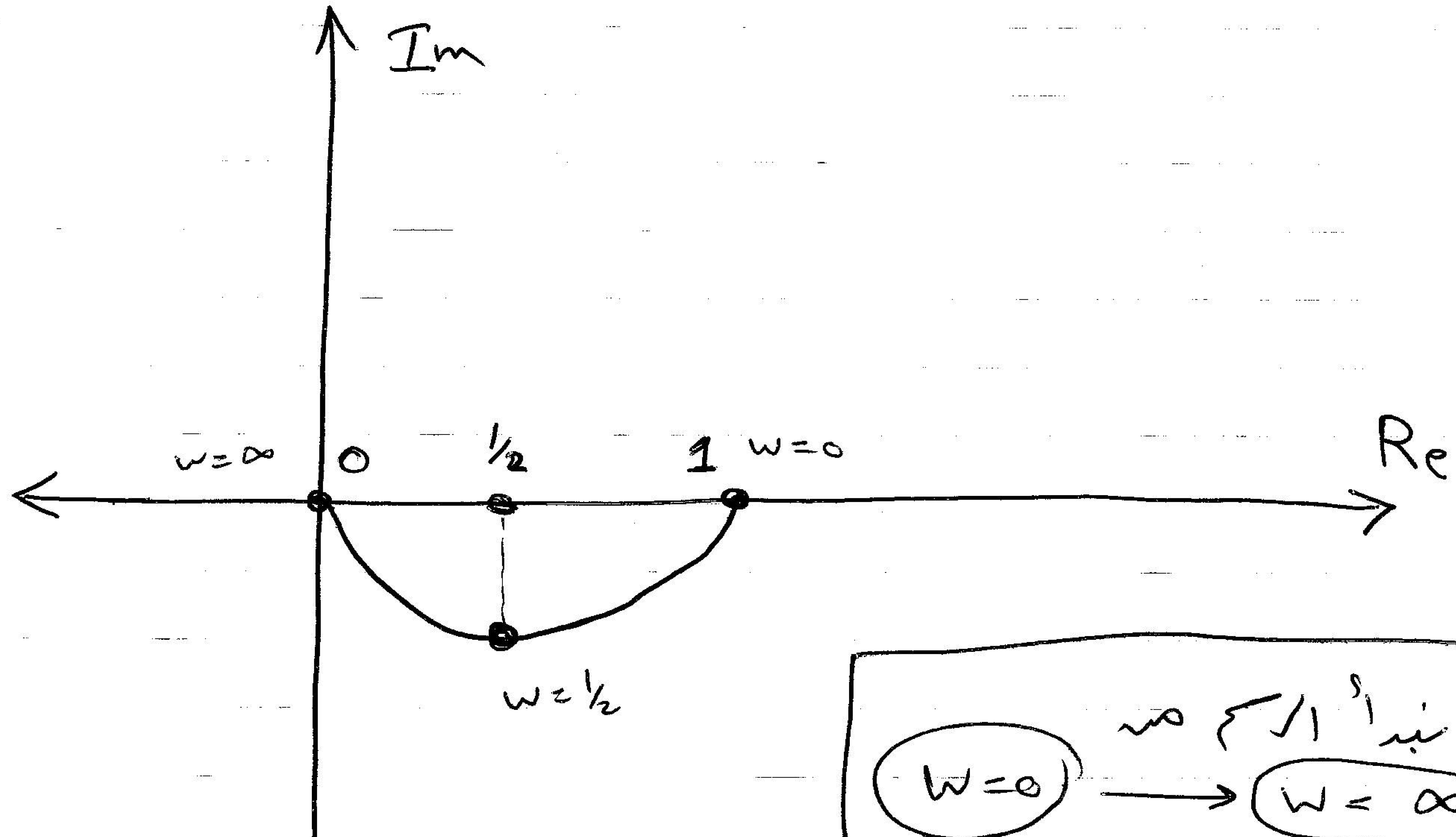
(1.) $G(s) = \dfrac{1}{2s+1}$

(1) $G(jw) = \boxed{\dfrac{1}{2jw+1}} * \left(\dfrac{2jw-1}{2jw-1}\right)$

$= \boxed{\dfrac{2jw-1}{-4w^2-1}} = \underbrace{\dfrac{1}{4w^2-1}}_{\text{Real Part } R(jw)} - \underbrace{\dfrac{2w}{4w^2+1}}_{\text{Imaginary Part } X(jw)} j$

(2)

W	0	1/2	∞
R(jw)	1	1/2	0
X(jw)	0	−1/2	0



نبدأ ارسم من

W=0 → W=∞

$\text{Gain} = \sqrt{\tfrac{1}{2}^2 + \tfrac{1}{2}^2} = \sqrt{\tfrac{1}{4}+\tfrac{1}{4}} = \sqrt{\tfrac{1}{2}} = \boxed{0.7}$

$\tfrac{1}{2}P = 0.7V = -3dB$